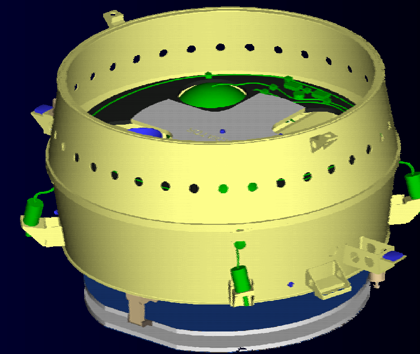
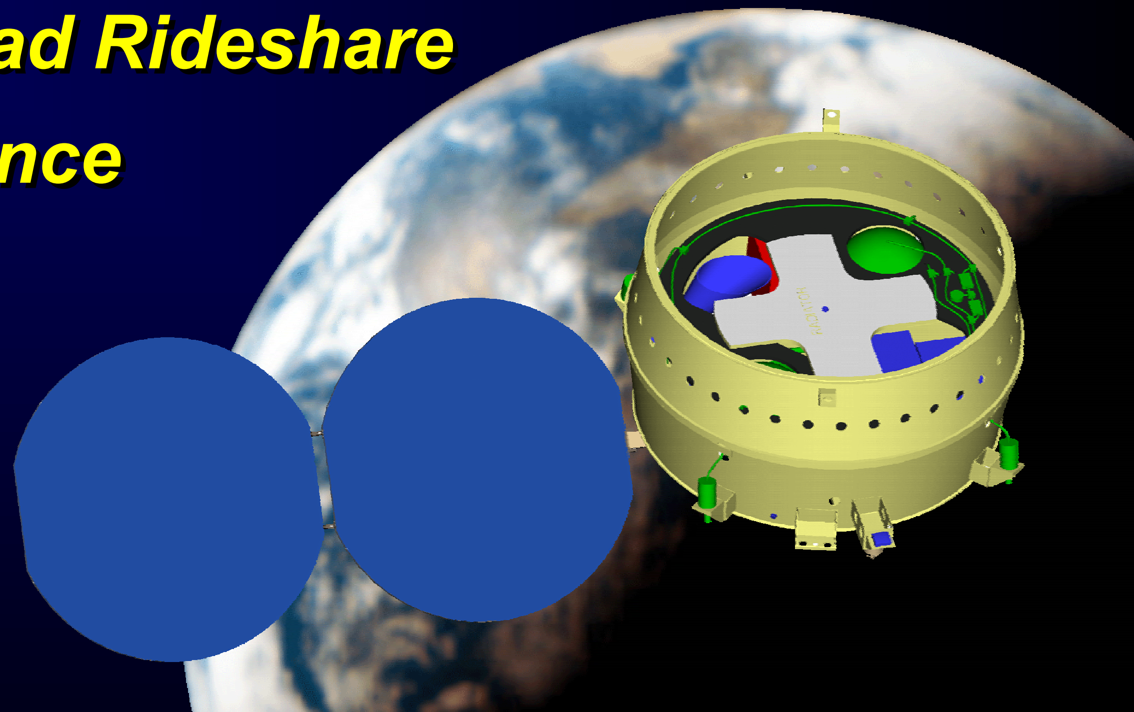
Space Accessibility Using I-Cone®



2003 Small Payload Rideshare Conference



SWALES AEROSPACE

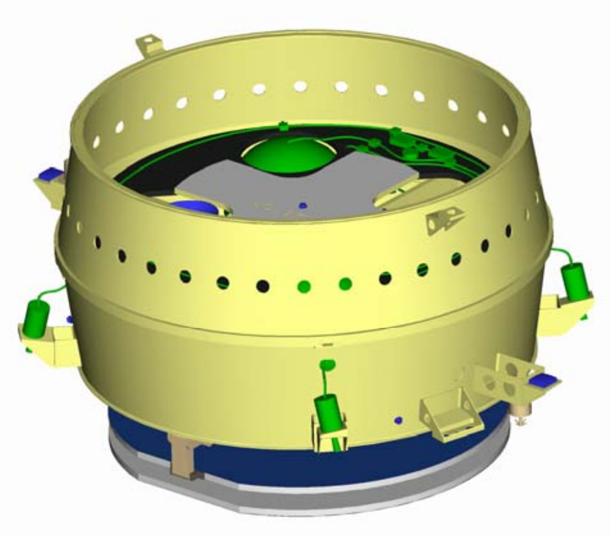
Saab Ericsson Space

Fast, Frequent, Flexible, and Affordable Access to Space

Historic Overview

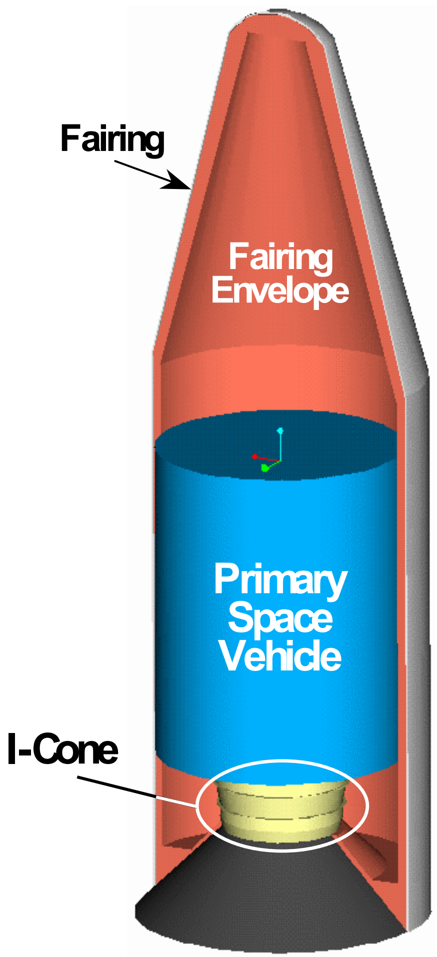
- Swales Aerospace and Saab Ericsson Space won a NRO study (NRO 0000-OIC-4369) contract for EELV applications in 2001, titled *Low Cost Enabling Technologies and Streamlined Design Considerations for Payloads and Spacecraft*

- Final Report Presentation to NRO
May 7, 2002



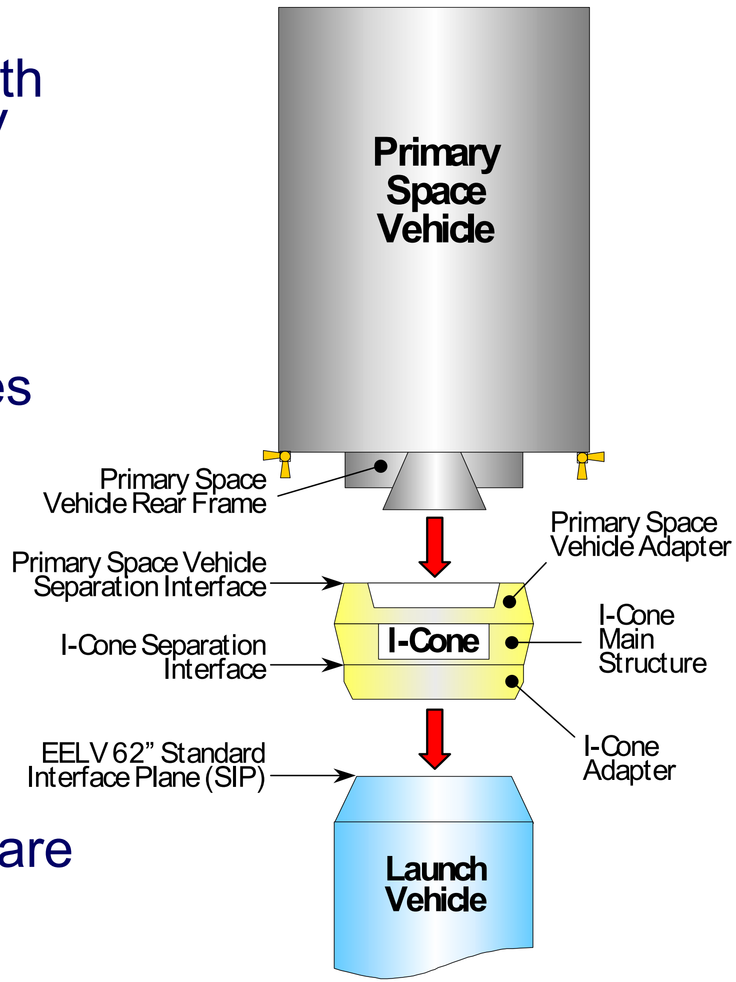
I-Cone Concept

I-Cone Goals



Launch Configuration

- Designed for use with Delta IV and Atlas V (EELV)
- Compatible with Delta II and Sea Launch Vehicles
- Lower launch cost
- Increased flight opportunities
- Low risk interfaces using heritage hardware and software
- Minimal impact to Primary Space Vehicle



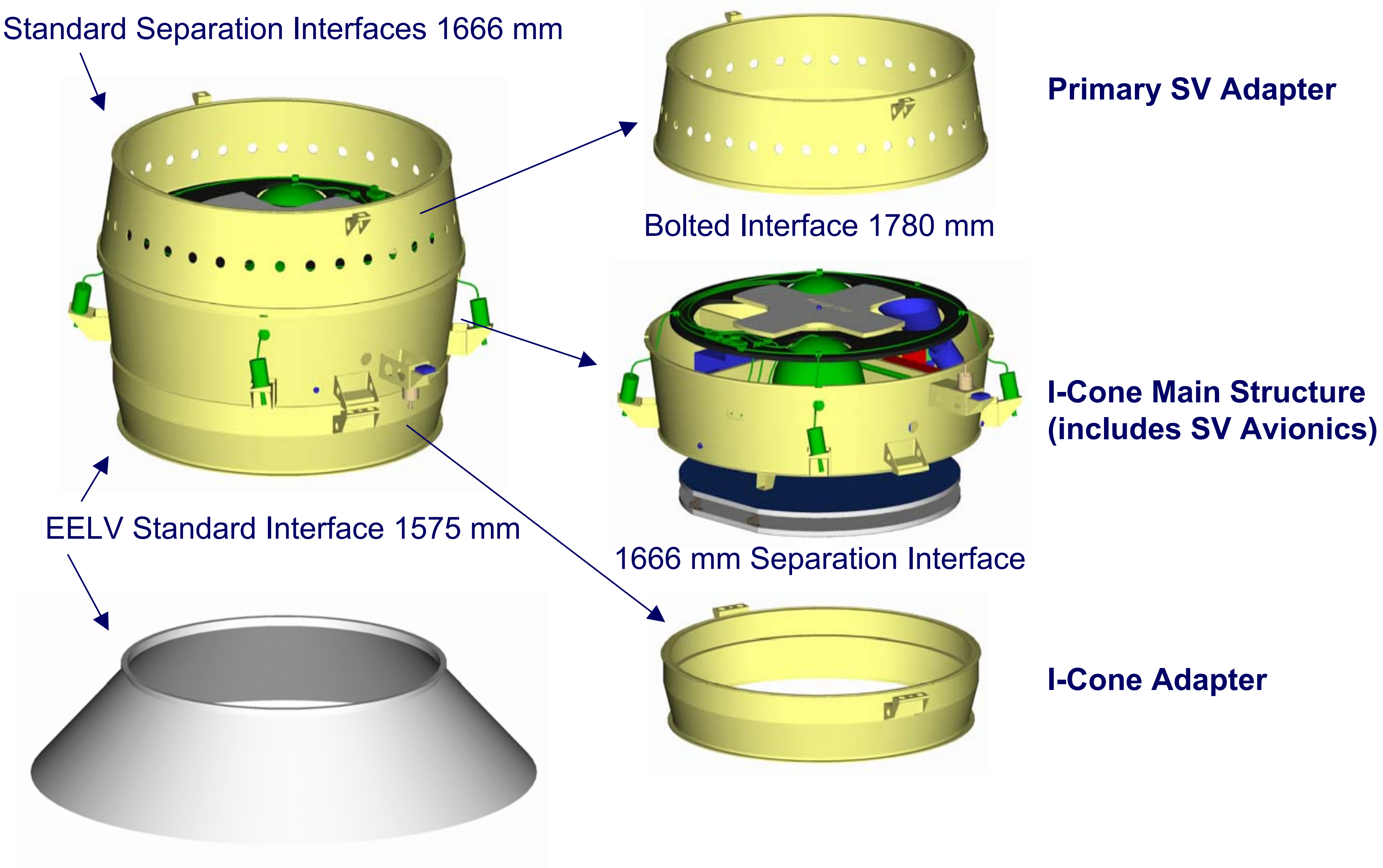
Nomenclature

I-Cone Requirements

- **Baseline System Requirements**
  - The I-Cone shall support a primary space vehicle mass of at least 5000 kg with CG at 2 m from the separation plane
  - The design of I-Cone shall minimize additional height, compared to the standard adapters used today
  - The design of I-Cone shall, as far as possible, use standard and commercial off-the-shelf (COTS) components and standard interface
  - The inner structure design shall have a modular approach to make the system flexible for different payloads
  - The I-Cone platform shall provide sufficient payload capacity, regarding mass, volume and power to enable a reasonably wide range of applications

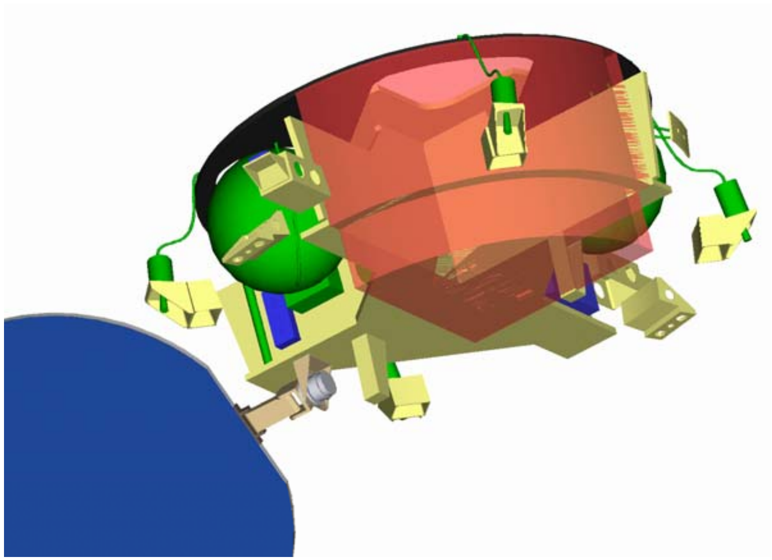
Baseline Mission Requirements	
Orbit	LEO (500-800 km)
Launch Vehicle	EELV from ETR or WTR
Mission Life-time	1 year post orbit checkout
Mass (NTE)	545 kg
Propulsion	Required for operational orbit insertion, maintenance and deorbit
Downlink Contact Time	60 minutes per day
Uplink/downlink Encryption	National Security Space (NSS) payloads only
Redundancy	Single string with selected redundancy

I-Cone Implementation



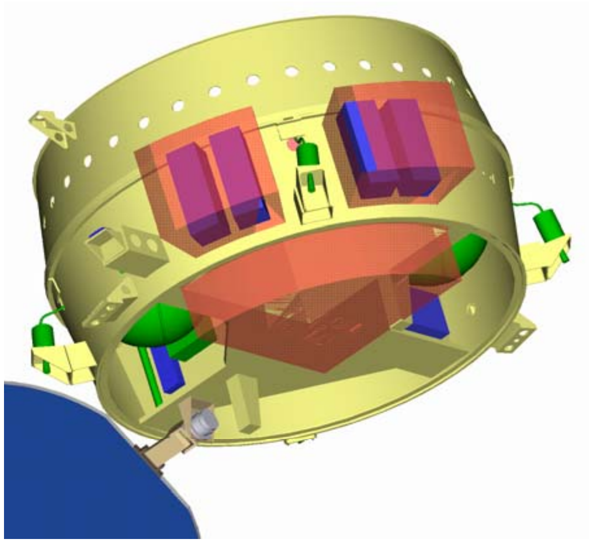
Payload Accommodation

Internal Payload Volume



Volume: 0.3 m³
Height: 720 mm

Outer Payload Volume

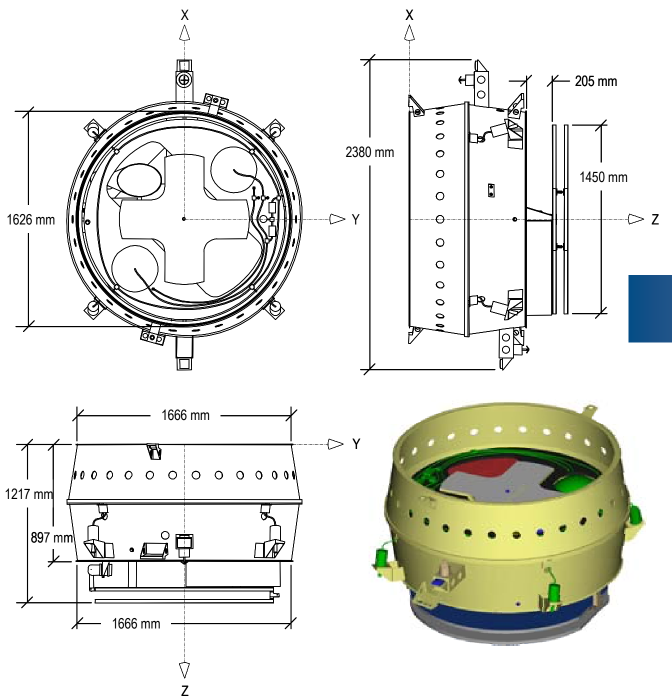


2 volumes:
365 mm * 270 mm * 380 mm

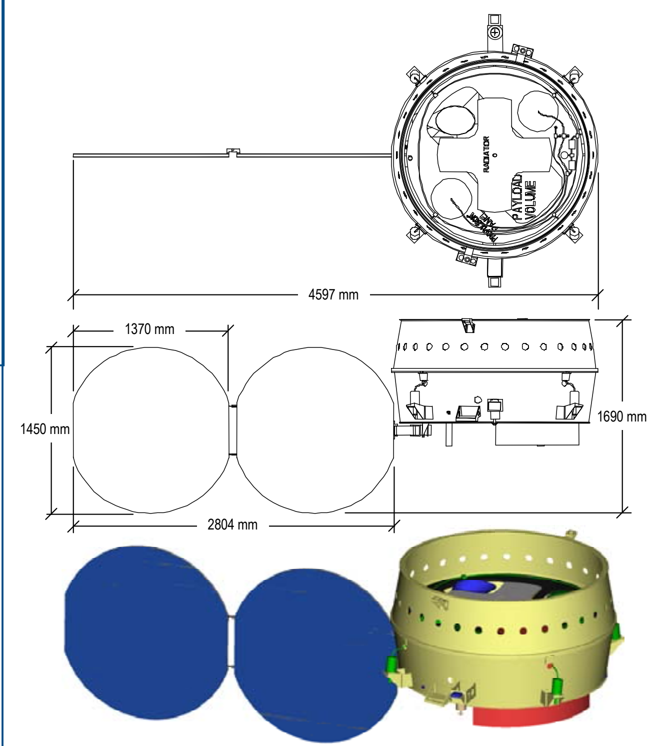
- Supports Payload Mass of 100 kg
- Provides 150 W orbit average payload power
- 5 Gbit minimum data storage capability
- RS-422 and 1553B Command and Data Bus
- Three Axis Stabilization provides Pointing Accuracy of 10-50 arcsec

I-Cone Baseline Implementation

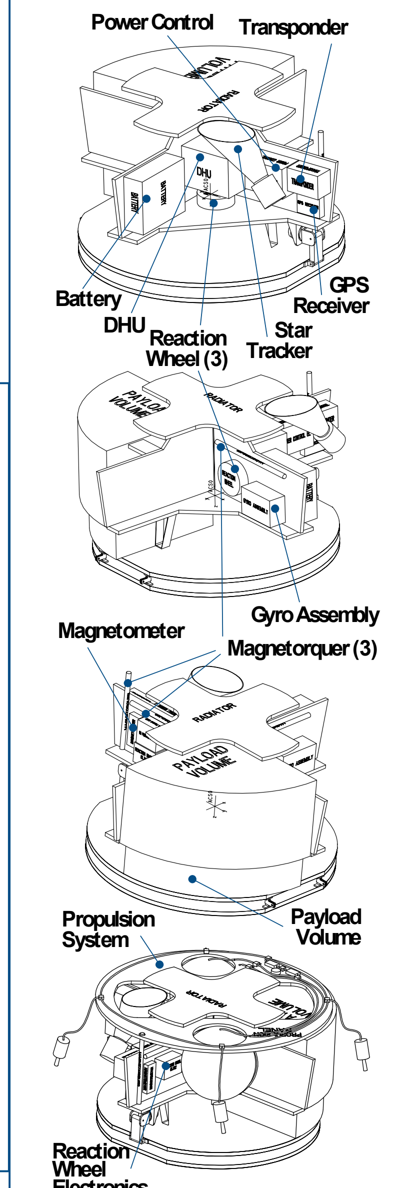
I-Cone Stowed Configuration



I-Cone Orbit Configuration



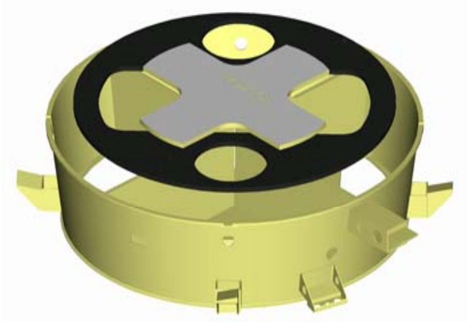
I-Cone Subsystems

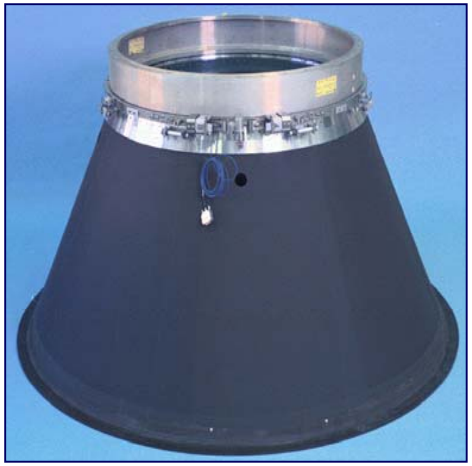


Structure Overview

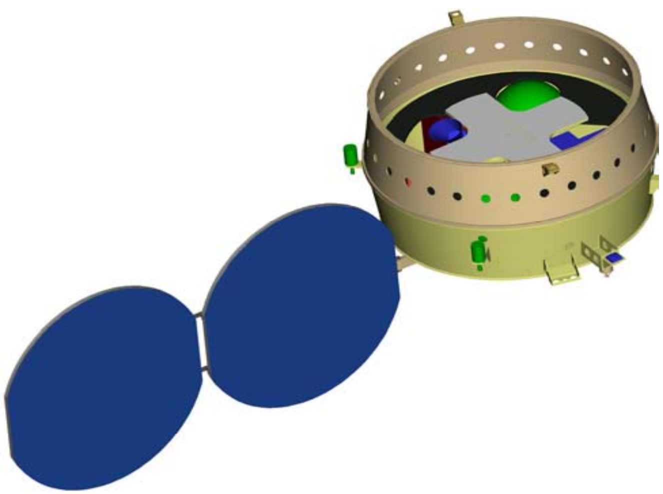
- Design is based on SES qualified adapter structures
- Possibility for different adapters to be used with the primary space vehicle
- Qualified separation systems
- Inner structure made of aluminum honeycomb panels provide for large mounting area
- Structure design provides for flexible and modular equipment and payload accommodation

Baseline





High Pointing Accuracy I-Cone
(BASELINE)

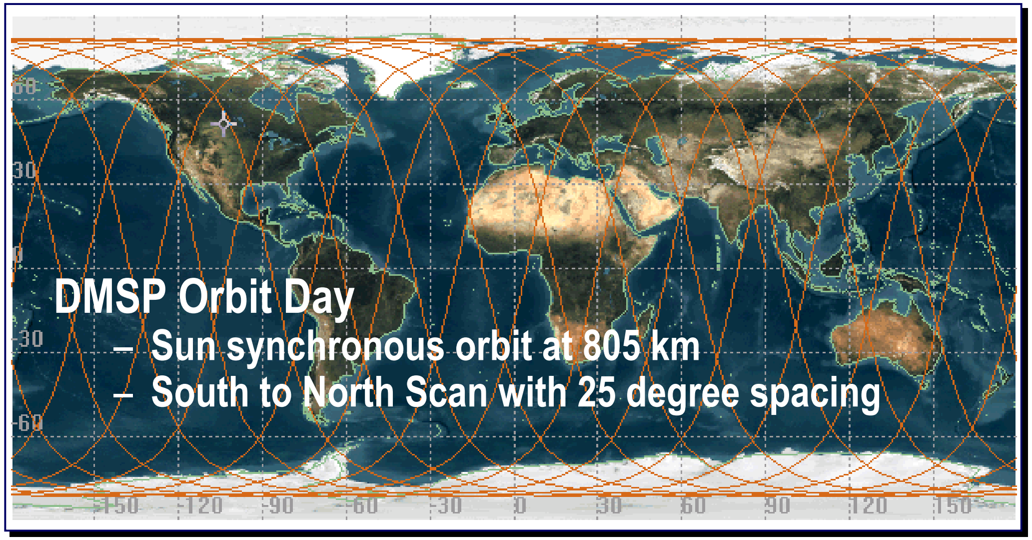


Baseline Configuration

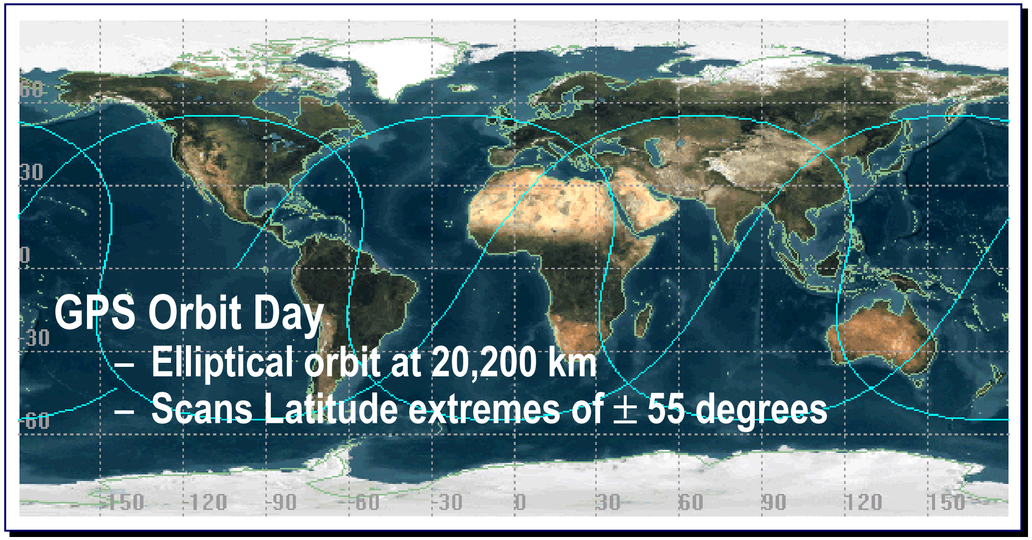
ITEM	PROPOSED BASELINE IMPLEMENTATION
Mission Life	Baseline designed for minimum of 1 year with consumables for 2+ years
Launch Vehicle	Standard 1666 separation interface in baseline approach with optional 1194, 1663, or 937 interfaces available; 1575 bolted interface to launch vehicle included
Mission Profile	Worst-case orbit parameters used in evaluation to bound system design; On-board propulsion system provides for launch insertion errors, small inclination changes, drag makeup, and deboost, Δ V = 410 m/s with 20% margin
Launch Readiness	Proposed 24 months for initial unit readiness for payload and 18 months for follow-on units
Payload Mass	Accommodated by the I-Cone inner structure and potential exterior mounted shelves
SV Mass	Maximum launch mass limited only by primary mission requirements and launch vehicle, 506 kg baseline estimate
Payload Power	28 VDC, four (4) switched services, with over and under current protection
SV Power and Margin	EOL 300 W Total system load prediction including 15% margin; (1) - 21 Ah battery max 33% DOD during worst eclipse; 2.6 m^2 deployable solar array is driven at orbital rate by single axis actuator
Thermal	Passive, cold-biased thermal design consisting of dedicated spacecraft and payload radiators; robust autonomous thermostatic control of resistive heaters
C&DH Architecture	Time tagged and event driven commands. Telemetry and I/O for payloads along with discrete analog / digital I/O
Payload Data Rate	Payload data rate accommodated: 48 kps with 1553 I/F and 2 Mbs with RS-422 I/F plus 16 kbs for SV housekeeping data
Data Storage	Standard DHU configuration can accommodate 5 Gbit and is expandable to 16 Gbit
CMD Interface	Both 1553B and RS-422 serial I/F provided
Guidance, Navigation, & Control (3 sigma values)	Three Axis Stabilization Employed - Zero Momentum (3 RWA), Gyro and Fixed Head Star Tracker, Pointing Accuracy of 10-50 arcsec achievable with SIRU upgrade
Communication	S-Band System, Omni Antenna; 2 Kbps Uplink: 2 Mbps Downlink Data Rate provides > 6db Link Margin six 8 minute contacts/day provides 25% margin relative to budgeted 60 minute downlink time
Radiation	All avionics are resistant to > 30 Krads dose and are SEU tolerant
Magnetic Cleanliness	2.5 A-m^2 Peak, Single-Axis Transient SV Control Magnetic Moment and a S/C Harness E/M Dipole of 0.72 A-m2 at the S/C Body Outer Surface are Worst Case Estimated Environments from SV
Redundancy and Fault Tolerance	SV bus is single string; some functional overlap and selective redundancy allows for increased fault tolerance. The over-voltage protection circuitry of the PCE provides for protection against exceeding the maximum bus voltage specifications and a degraded mode of operation for battery charging

Delta V / Ground Tracks

I-Cone ΔV Budget – DMSP Launch	
Circularize Orbit at 500 to 805 km	169.7 m/s
Lower Perigee to 400 km reentry	109.0 m/s
Orbit Maintenance	60.0 m/s
Margin (20%)	68.1 m/s
Total Δ**V** Requirement	406.8 m/s



I-Cone ΔV Budget – GPS Launch	
Boost Perigee to 800 km	87.7 m/s
Lower Perigee to 400 km reentry	56.7 m/s
Orbit Maintenance	90.0 m/s
Margin (20%)	68.6 m/s
Total Δ**V** Requirement	303.0 m/s



System Budgets

Mass Budget

Subsystem		Mass (Kg) In-Orbit	Mass (Kg) Launch
I-Cone Spacecraft Structure		182.3	182.3
I-Cone Adapter and Separation System		0.0	47.3
Power Subsystem		44.8	44.8
Data Handling Unit		11.0	11.0
Communication Subsystem		4.2	4.2
Harness		10.0	10.0
Thermal Subsystem		5.0	5.0
Attitude Control Subsystem		19.4	19.4
Propulsion		17.8	14.6
I-Cone Bus Dry Mass		**294.5**	**341.8**
Contingency	15%	51.0	51.0
I-Cone Bus Dry Mass with Contingency		**345.5**	**392.8**
Hydrazine Propellant Consumable		90.0	90.0
Payload		100.0	100.0
I-Cone Space Vehicle – Fully Integrated and Fueled		**535.5**	**582.8**
Primary space vehicle Adapter	See Note Below		(50.4)
Primary space vehicle Separation System	See Note Below		(18.9)
Adapter Harness	See Note Below		(5.3)
1575 mm mounting bolts	See Note Below		(2.1)
Added Launch Mass			**506.1**

Note:

Mass of these components are subtracted from overall I-Cone system launch mass since these items are required for EELV regardless of I-Cone.

Power Budget

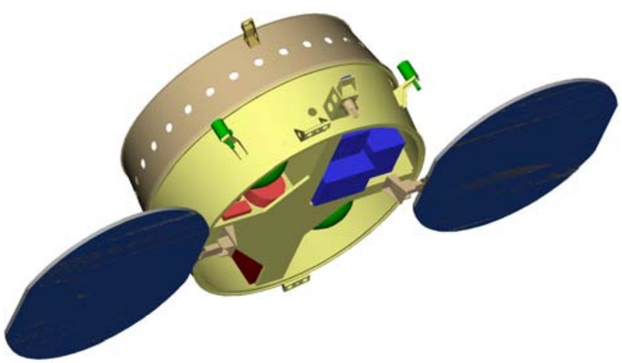
Subsystem	Orbit Avg. Power (Watts)
DHU	20.0
Power (harness losses not budgeted)	18.0
Attitude Control	47.1
Communications	8.5
Thermal	15.0
BUS TOTAL	108.6
Payload (allocated)	150
SPACE VEHICLE TOTAL	258.6
Contingency (16%)	41.4
TOTAL	300

Note:

Power Budget assumes 100% duty cycle for all components during nominal operations, except the RF transmitter, which has a 10% duty cycle

Medium and Low Pointing Accuracy

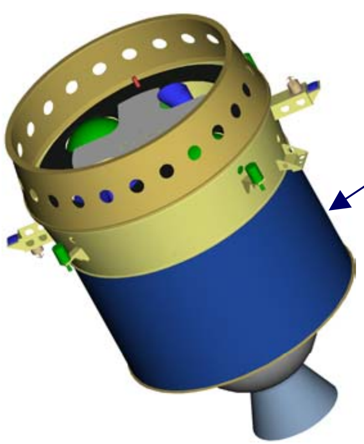
- **Momentum Bias System**
  - Accuracy range of 0.05 - 0.1 deg
- **Spin Stabilized or Gravity Gradient**
  - Accuracy Range of 1 - 10 deg



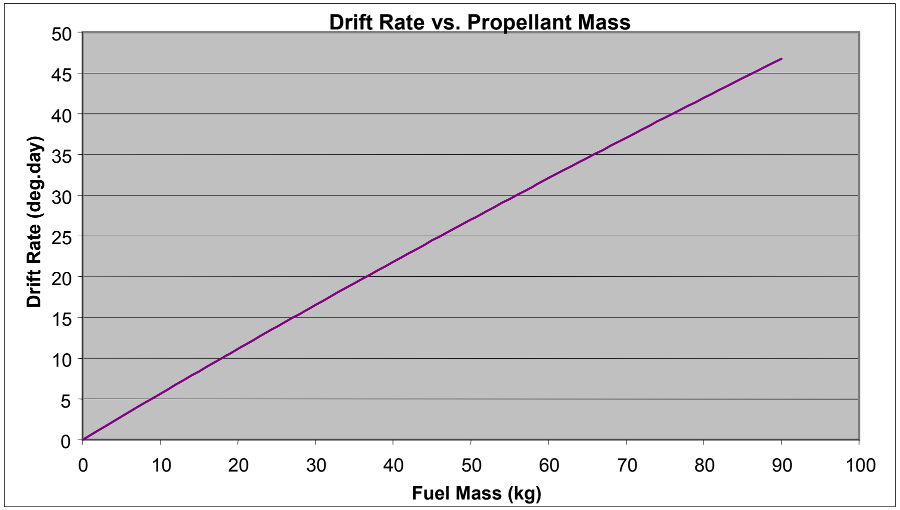
CONFIGURATION	SENSORS	ACTUATORS	ACCURACY	MISSION / ORBITS
1	1 Horizon sensor 1 Fine sun sensor 3 Coarse sun sensors 3 Gyros 1 GPS	1 Momentum wheel 3 Magnetorquers	Pitch: ~0.06° Other axis: > 0.5°	Polar orbits / high inclination, LEO
2	1 Horizon sensor 1 Fine sun sensor 3 Coarse sun sensors 3 Gyros 1 GPS	1 Momentum wheel 1 Reaction wheel 3 Magnetorquers	~0.06°	Polar orbits / high inclination, LEO
3	1 Horizon sensor 1 Fine sun sensor 3 Coarse sun sensors 3 Gyros 1 GPS	1 Momentum wheel 1 Reaction wheel 8 Thrusters (cold gas or Hydrazine)	LEO / MEO: ~0.06°	Low inclination, LEO / MEO orbits
4	1 Horizon sensor 1 Fine sun sensor 3 Coarse sun sensors 3 Gyros	1 Momentum wheel 1 Reaction wheel 8 Thrusters (cold gas or Hydrazine)	GEO: ~0.06°	GEO orbits

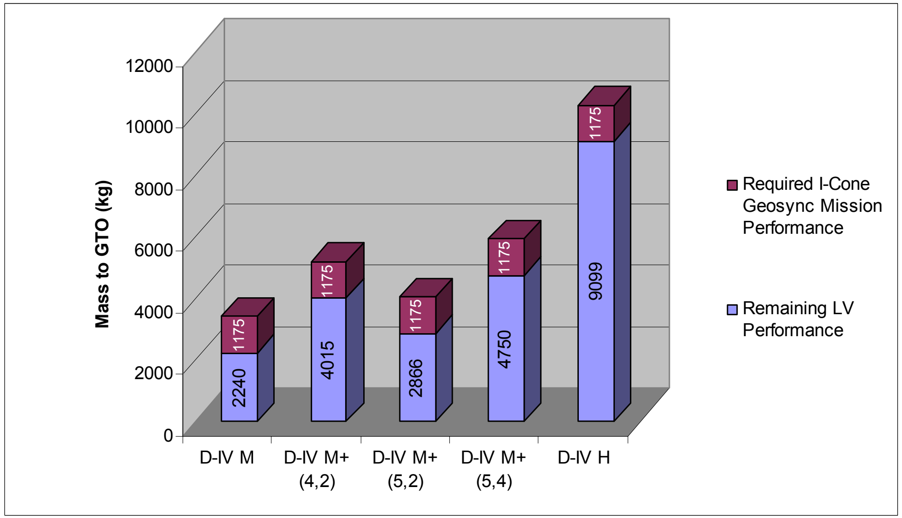
Geo I-Cone

- **Geosynchronous Orbit**
- **Use any AOCS control system defined in SV configurations**
- **Geo I-Cone will be spin-stabilized during the AKM burn. The hydrazine system will provide the spin-up and de-spin impulse**
- **Geo-Transfer stage will be jettisoned after burnout**



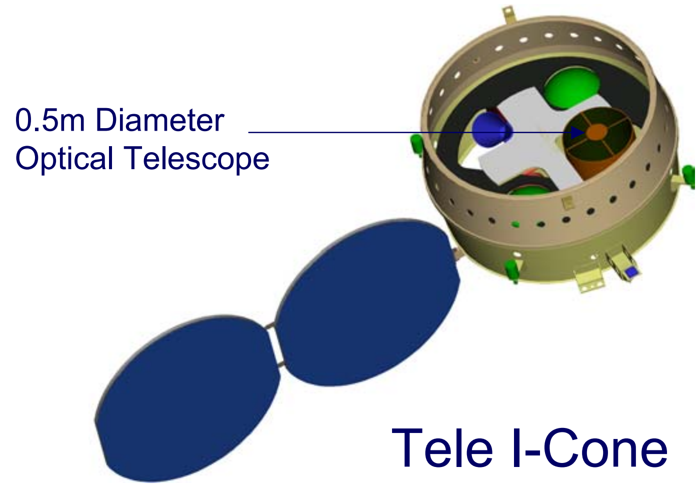
Geo-Transfer Stage with Star 37XFP AKM



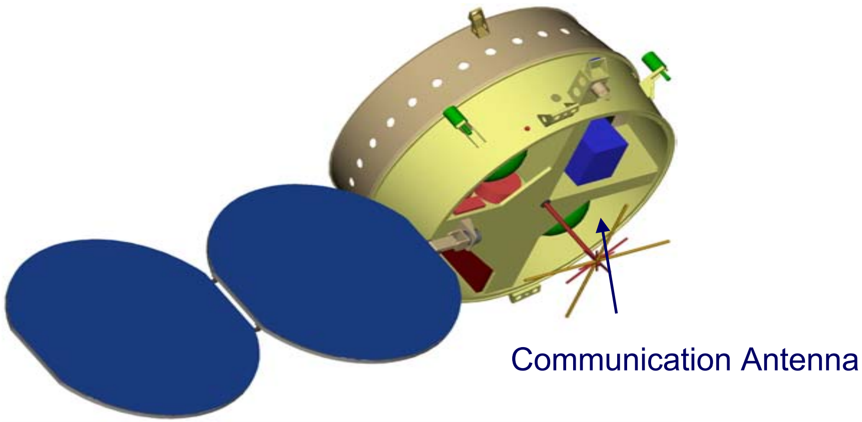


Geosync Performance of a Delta IV EELV with I-Cone

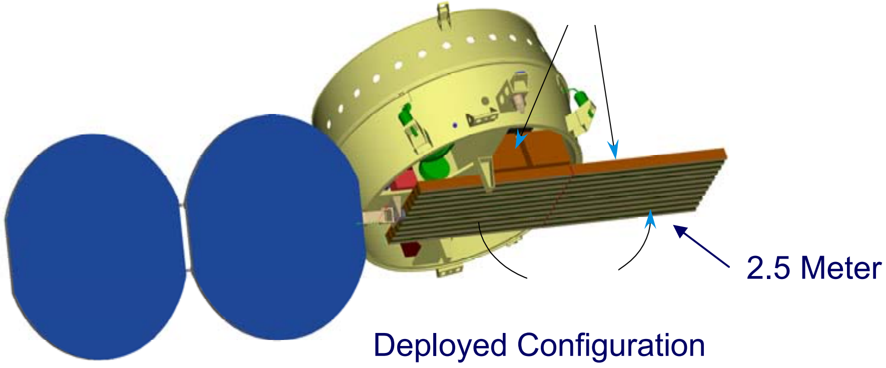
I-Cone Payload Examples



Tele I-Cone



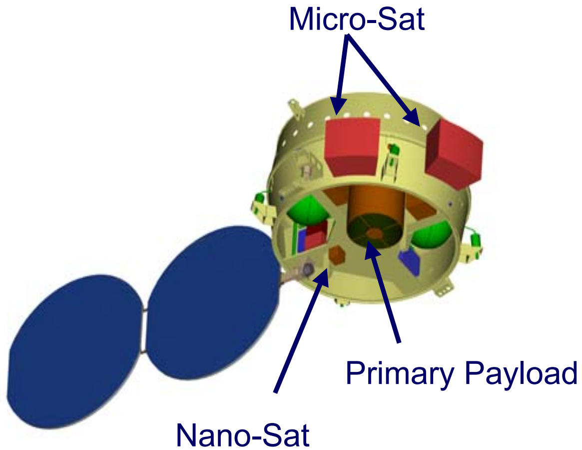
Communication I-Cone



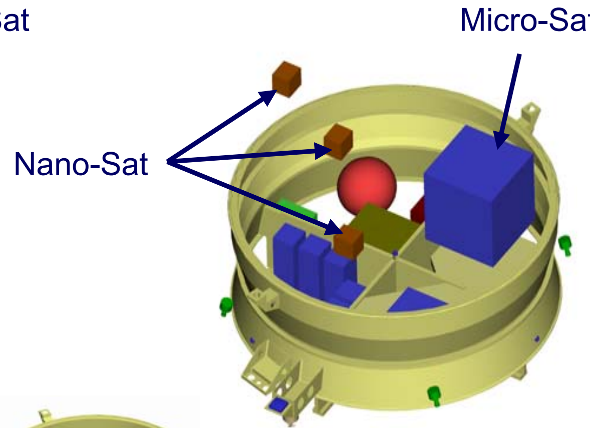
SAR I-Cone

I-Cone as a Dispenser

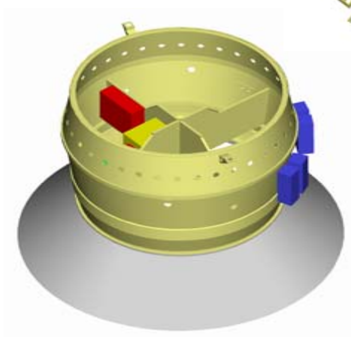
- **Active Dispenser**
  - Carries micro / nano-Sats
  - May carry payload for mission demo
  - SES nanoSat release system available



- **Reduced Height Dispenser**
  - Alternate adapter configuration
  - Similar capability as the active dispenser
  - No height impact for Atlas V – 500



- **Passive Dispenser**
  - Non-separable from LV
  - Carries micro / nano-Sats
  - Uses LV for pointing control and release initiation

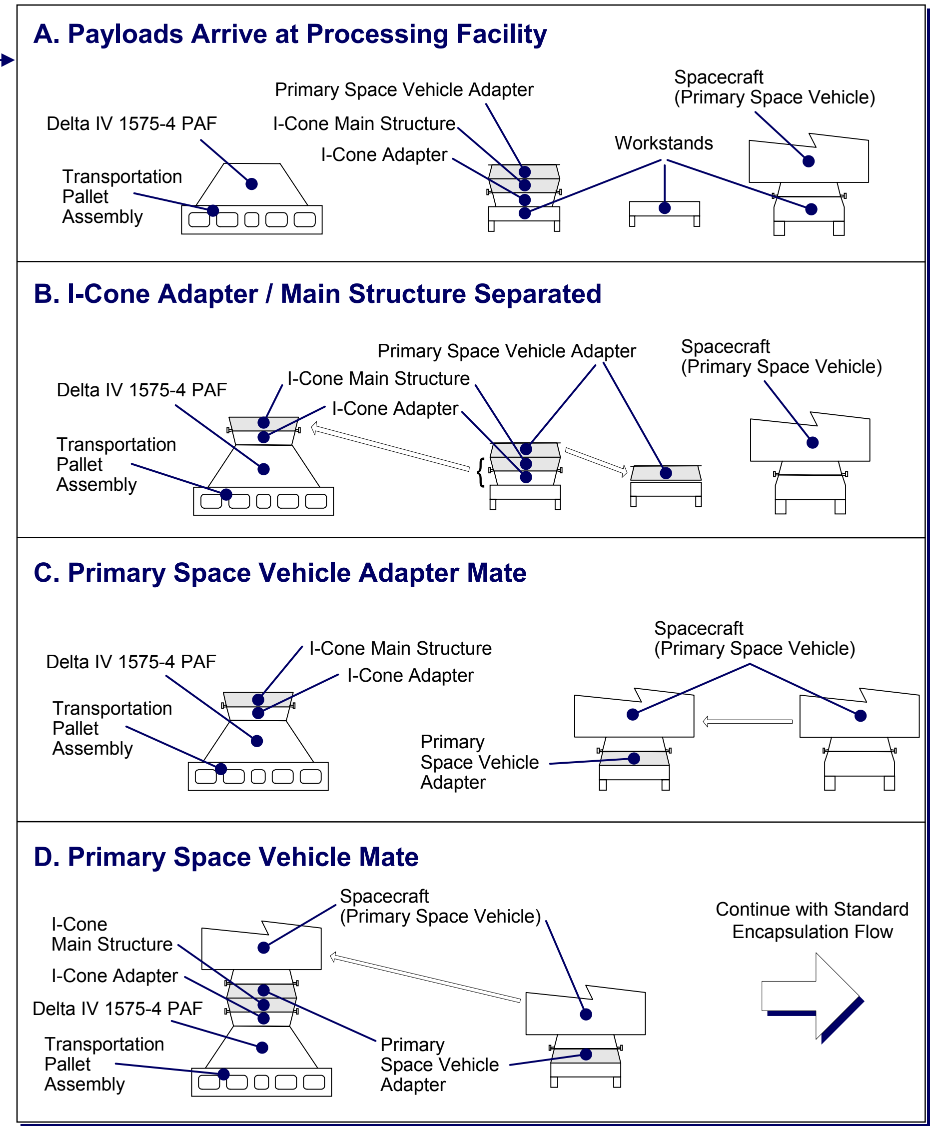


I-Cone Minimizes Impact to Primary Space Vehicle

Pre-Encapsulation

1. I-Cone Arrives at Launch Site
2. Setup Electrical GSE
3. Post-Ship Functional and Comprehensive Performance Test
4. I-Cone Fueling
5. Final Weighing
6. Ready for LV Integration

Encapsulation Flow



Where do we go from here?

NSS

- **I-Cone can be further developed to meet the specific needs of candidate missions**
  - Detailed assessment of impacts to Primary Space Vehicle
  - Vehicle assessment
  - Orbit assessment
  - Payload interface assessment
  - Delta V requirements
  - Pointing analysis
  - Dispenser sizing
  - Subsystem optimization

NASA

- **Delta II Assessment**
  - Repackage subsystems for smaller adapter
  - Revise performance baseline
  - Assess potential candidate missions